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ILLUSTRATIONS OF HEART-SOUND RECORDS

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With Plates 19-25

Method.

THE method employed to register the sounds produced by the heart, described in the present paper, which is very similar to that recently described by Einthoven(1) and Fahr (3), is shown schematically in Fig. 1. A large and sensitive microphone (M) communicates with the air through thick-walled rubber tubing and a stethoscope end-piece (s). The tubing has a second outlet (o), which remains permanently open. Its purpose is to avoid the combination of heart-sound record with that of slow movements of the chest wall due to the heart-beat. The microphonic circuit includes a dry cell, a make-break key (K^2), a rheostat ($R=70$ ohms), and the primary coil (10 ohms) of an inductorium or transformer (T). The secondary coil (coreless, 5,300 ohms) of the transformer is connected to a short circuiting key (K^1); this key, when closed, forms a shunt to the fibre of the string galvanometer (G). Sound vibrations, transmitted through the stethoscope, fall upon the microphonic plate and by pressure produce variations in the internal resistance of the microphonic circuit; the current flowing through this circuit is varied accordingly, and, varying, induces currents of higher potential in the secondary circuit; these secondary currents flow directly through the string when the shunt (K^1) is open. The string galvanometer, on account of its sensibility, readily records these currents when they flow through it. In using the string galvanometer in this manner, it is necessary that the fibre should be relatively tense. The tenser it is the more capable is it of rapid movement. I have employed the instruments modelled by the Cambridge Scientific Instrument Company, and, working with silvered glass fibres in the recording galvanometer, have found that oscillations having a frequency of 660 per second may be recorded with facility when the string is very tense. At such

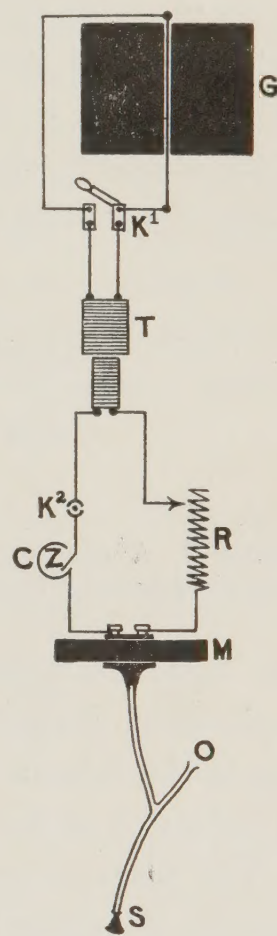


FIG. 1. A diagram of the electro-phonograph.
M = Microphone;
S = Stethoscope;
R = Rheostat;
O = Outlet;
C = Dry cell;
T = Transformer;
G = String galvanometer;
K = Keys.

¹ The expenses of this work have been defrayed by a grant from the British Medical Association.

a tension that 4 millivolts yield 1 cm. excursion, the string's deflexion time is approximately 0.004 second. The two deflexions, or a complete vibration, would occupy 0.008 second. With the string at this tension a sound having a frequency of 125 per second would be recorded at an amplitude of 1 cm. without damping. In the case of the majority of the observations here recorded the deflexion time was less ; so that vibrations having a frequency of 250 or more per second appear unchanged in the records at amplitudes of 1 centimetre and less.

The sound curves described are not standardized, so as to provide comparisons of amplitude from curve to curve, for the reason that no method of sufficient reliability is as yet available for the purpose. The excursion of the string is simply controlled so as to provide curves of suitable size for reading the events in relation to the times of their occurrence.

As the most reliable standard with which to gauge the relation of acoustic events to systole and diastole in the heart, electro-cardiograms from the second lead (right arm to left leg) have been chosen and taken simultaneously. The two installations, electro-phonograph and electro-cardiograph, are arranged side by side, the shadows of the two strings converging slightly and falling upon the

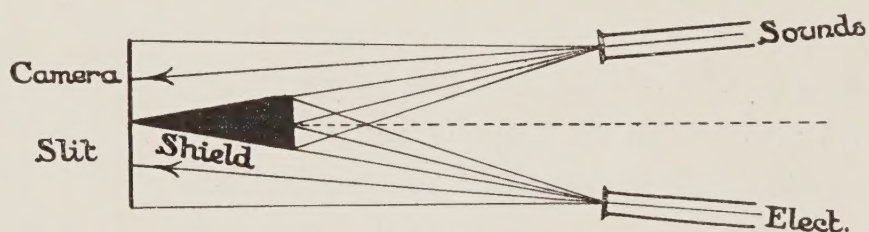


FIG. 2. A diagram illustrating the optical arrangements used in taking simultaneous electro-cardiograms and heart-sound records.

same horizontal slit (Fig. 2). To separate the light, diverging from the two eye-pieces of the galvanometers, a triangular shield is arranged with its point lying at the camera slit. Overlap of the light from two sources is thus avoided and definition of the pictures is sharp.

The plate moves at right angles to the line of the slit and is ruled (in the direction of motion) by lines drawn upon a cylindrical lens placed in the slit. These lines are seen in the figures ; supposing the motion of the plate to be exactly at right angles to the slit, then any line drawn at right angles to the direction of travel will cut the two recorded curves at points representing the same instant of time. In the figures, a line at right angles to the horizontal represents a given instant with an error so small as to be negligible (the line of motion in my apparatus is not absolutely at right angles to the slit, and the heart-sound record, relative to the electro-cardiogram, is delayed by an interval of not more than 0.0005 to 0.001 second, according to the speed of the travelling plate and the distance of one record from the other).

A calculation has to be made for the transmission of the sound through the recording apparatus ; this may be measured by arranging a contact between two pieces of metal so that the contact sends a small current through one galvano-

meter while its sound is recorded by the other (Fahr). The delay of the heart-sound record in the present curves from this cause is a little less than 0.002 second. The total delay from all causes amounts to about 0.003 second. This fraction has been allowed in the calculation of intervals subsequently mentioned in this paper.

Experimental Observations.

The experiments have been conducted upon animals anaesthetized with morphia, paraldehyde, and ether. The heart-sounds have been recorded from the shaved chest wall, the stethoscope resting over the lower third of the sternum or an inch or more to the left of the sternum in the 5th or 6th intercostal space.

The heart-sounds are readily recorded in the dog; though, to obtain good records, it is necessary to eliminate breath-sounds. Artificial respiration was employed, therefore, the pump being stopped immediately before a record was taken. Simultaneous electro-cardiograms were taken from the right fore-limb and left hind-limb, and sometimes a simultaneous carotid curve from the middle of the artery in the neck by means of Hürthle's manometer. The relation of the sounds to the several electro-cardiographic deflexions is not constant. They are exemplified by the accompanying table, which also includes the approximate lengths of first and second sounds.¹ The readings are averages of a number of measurements (Figs. 3 and 4).

	Heart rate.	Commencement of Q to First Sound.	Commencement of R to First Sound.	End of T to Second Sound.	Length of First Sound.	Length of Second Sound.	Frequency of Vibrations.	
							First.	Second.
Dog DE	131	0.017	0.010 or less	-0.016	0.14	0.06	48	60
Dog DF	136	(Q) absent	0.004	-0.051	0.19	0.04	52	75
Dog DJ	121	0.024	0.018	0.023	0.13	0.09	70	89
Dog DK	130	0.029	0.027	-0.011	—	—	84	86

The first heart-sound commences 1 or 3 hundredths of a second after the upstroke of the summit R, and a little more than this after the depression Q. The second heart-sound usually begins before the end of the down-stroke of T, and this interval may extend to 0.05 second, but more commonly is much less; T may end before the second sound appears. These figures correspond very closely to those of the normal human subject. In dogs the first sound is approximately double the length of the second, and has usually double its amplitude, though the pitch of the latter is somewhat higher. In the human subject the first sound is also much louder than the second, but sometimes the reverse is true; it is also much longer than the second, but the average frequency of vibration in man is very similar for both. As regards the character of the two sounds, in both man and dogs the first sound, as is well known, is more booming to the ear, while the second has a sharper quality. The difference is

¹ The third sound has not been observed in dogs.

not constant, however, but when present it seems to result from the amplitudinal relations of the separate vibrations in the two sounds. The first sound is generally crescendo in amplitude at first and subsequently diminuendo, while the initial vibrations of the second sound are often the most intense and the sound as a whole is then a simple diminuendo (Fig. 5). The sounds begin differently but end in the same fashion.²

When respiration is in abeyance, the forms of the curves are wonderfully constant from cycle to cycle, the sound vibrations are usually repeated in all their detail (Figs. 3 and 4).

The influence of rise of aortic pressure upon the sounds. It is commonly taught that rises of blood-pressure produce an accentuation of the second heart-sound; certain it is that high arterial pressure is often accompanied by such accentuation, but that the last depends upon the first is clearly negatived by simple experimentation. In a number of animals I have studied the effects of a rise of blood-pressure, such as is induced mechanically by obliterating the abdominal aorta, upon the sounds, and in no instance have been able to detect any appreciable alterations; neither have I been able to hear or record any tendency to reduplication under similar circumstances. In Fig. 6 the diastolic pressure rises from 45 to 62 mm. Hg., the systolic rising from 95 to 125 mm. Hg., while the heart-sounds remain quite unchanged.

Of the factors which influence the intensity of heart-sounds none seems so important as the intactness of the chest wall. In the dog, the introduction of the smallest quantity of air has a profound damping influence, so much so that in studying heart-sounds in this animal the chest wall must be religiously respected. Repair of the chest wall does not as a rule restore the sounds. In this animal too, a number of experiments are abortive on account of the complete and unexplained loss of the second sound early in the course of the experiments.

The effects of change of rate, on the other hand, are pronounced and uniform. A rise of rate is accompanied by a diminution in the amplitude of both sounds. The duration of the sounds is much less affected (Fig. 7).

Murmurs in artificial aortic disease. The aortic valves are easily damaged by introducing suitable instruments through the carotid in the neck, and the murmurs which result in the dog are very audible over the front of the chest wall. When, as usually happens, a single cusp is pierced and torn through to its margin, the second sound is still recorded, but it is accompanied and followed by a number of fine vibrations the frequency of which is approximately 100 to 120 per second (Fig. 8). They are generally regular in incidence and uniformly diminuendo. The amplitude is never great, being far less than that of the vibrations of the second sound; it may require close examination of the curves to detect them. In a solitary experiment, in which a dorsal aortic cusp was broken, a second murmur, having a lesser frequency of vibration, appeared in

² The syllabic equivalent to the heart-sounds, 'lub-dup,' is a most imperfect expression of the sounds. Records of the spoken syllables bear not the slightest resemblance to the natural sounds.

presystole (Fig. 9). In the record it clearly resembles a presystolic murmur of mitral origin and brings to mind the murmurs described in aortic disease by Flint (4).

Grouping of heart-sounds produced by irregularities. Acceleration of the heart's action has, as has been stated, a considerable influence upon the amplitude of the sounds and a lesser influence upon their duration. Now when there is an increase of rate, the pauses between the beats are reduced, and it is to this that the alteration of the heart-sounds is due. Premature contractions are preceded by relatively short pauses and the sounds which accompany them are altered, as are the sounds produced by rapid action. The sounds of a dog's heart in which occasional premature beats were excited are shown in Fig. 10. Two normal cycles are shown, and these are followed by a premature beat (of auricular origin). The premature first and second sounds are both reduced in amplitude and the duration of the second sound is curtailed. The character of the sounds is altered. The interval between first and second sounds is shortened also. The first beat after the pause is accompanied by a louder and longer first sound, but the corresponding second sound is not much affected.

If the premature beats occur very early in diastole, the first sounds are conspicuously reduced both in amplitude and duration, and may undergo a considerable change in character, while the second sound may vanish altogether. This, as is universally recognized, results from failure of the weak premature contraction to raise the aortic valves (Fig. 11). Curious groupings of the heart-sounds occur when premature beats recur frequently and in regular fashion. Two examples are shown in Figs. 11 and 12. In Fig. 11 the heart is beating in couples; a premature contraction of auricular origin follows each normal heart-cycle. The normal heart-beat is accompanied by first and second sounds, and the latter is immediately followed by and fuses with the first sound of the premature beat; the corresponding second sound is not present. The coupled heart-beats gave rise to tripled heart-sounds which were clearly audible. The reduction of the premature first sound in both amplitude and duration is conspicuous, also its character is greatly modified; it consists of three rapid and almost uniform vibrations, together occupying about $\frac{1}{30}$ second; were it longer it could not be distinguished from a murmur. Coupling of the heart-beats from the same cause and in the same animal is shown in Fig. 12; but here there is a wide gap between the individual beats of a couple. The premature beats are effective in raising the aortic valves, and the heart-sounds consequently occur in groups of four. The amplitudes of the sounds accompanying the premature beats are reduced as usual, and these systoles, as measured from the commencement of first to second sound, are relatively short.

When the auricles fibrillate and the ventricle responds irregularly, the sounds are modified accordingly. They vary in amplitude and duration and the distance between first and second sound varies in duration from beat to beat, according to the length of the preceding pauses, and when a pause is very short the succeeding second sound is absent (Fig. 13).

Clinical Observations.

The heart-sounds of the normal human subject have been described in another paper (8); so also have the acoustic phenomena in cases of mitral stenosis.

Mitral regurgitation. I have found considerable difficulty in recording the systolic apical murmur in a large percentage of cases of simple mitral regurgitation, and have been impressed by the smallness of its amplitude in most cases. We know that it often conveys the impression of distance, but until its registration was attempted I had no conception of the degree in which the first sound predominates over it. Naturally, it is often buried in the first sound, and under such circumstances may show itself in the form of small secondary vibrations upon the large vibrations of this sound. But sometimes it is almost imperceptible in the curves (Fig. 14), though clearly perceptible to the ear. In the original of Fig. 14 (s.m.), very fine oscillations can be seen, following upon the first sound; they are scarcely visible without the aid of a magnifying glass. In taking records and auscultating the chest at the same point from time to time, one is greatly impressed by the power of the human ear and centres of reception in discriminating between sound and murmur.⁴ When a systolic murmur is present in conjunction with the first sound, the microphone records both; the ear detects one or other and exaggerates it according to the degree and direction in which the mind is concentrated.

A systolic murmur, occurring in mid-systole, commencing with the end of the first and ending with the commencement of the second sound, is seen in Fig. 15. It consists of fine-cut and almost uniform vibrations, having a frequency of about 112 per second. It had a very faint musical quality. Another similar example, in which the frequency is about 140, is shown in Fig. 16.

Aortic murmurs. Of aortic murmurs I have a number of records. A rough to-and-fro murmur is shown in Fig. 17. It was taken at the second cartilage, at which point neither first nor second sounds could be heard. A trace of first sound, nevertheless, is seen in the record. It is recognized by its low frequency. The vibration frequency is very variable during both systolic and diastolic phases; it averages about 80 per second. Both murmurs are diminuendo, the systolic being the louder. The two are together practically continuous, and the intensification which marks the commencement of the diastolic murmur falls very far to the left in relation to T in the electro-cardiogram.

Of loud musical diastolic aortic murmurs I have two examples: one is shown in Fig. 18. It is characterized by the *uniformity* of the vibrations, whose frequency is 138 per second. The murmur lasts about 0.24 second. In the second example in my possession the amplitude is much greater than that of the first sound; the duration is 0.14 second, and the frequency of vibration 180.

⁴ This discrimination may be emphasized by the statement that, in many cases of heart affection, a continuous noise is present, even when respiration is suspended. This noise passes unperceived by the ear unless attention is specially fixed upon it.

Pulmonary stenosis and patent ductus arteriosus. The exact diagnosis of congenital heart-lesions presents many difficulties; but in one group of patients, continuous or almost continuous thrills and murmurs occur in the region of the pulmonary cartilage, and these patients, as has been emphasized by Gerhardt (5) and Gibson (7), have patency of the ductus arteriosus. The patency of the ductus may or may not be associated with stenosis of the pulmonary orifice, and, from the character of the actual murmur, the presence or absence of this second defect cannot be decided.

The continuous murmur is, as a rule, coarse and loud, and is accentuated from time to time. Its duration is also curtailed from time to time, varying both in intensity and duration with the acts of breathing and with other causes. I give several illustrations of these murmurs in Figs. 19-21. The murmur is most intense in systole and follows immediately upon the first sound. In my examples it increases in intensity during systole; it does not decrease, as does the systolic murmur of aortic disease (Fig. 17), but reaches its greatest intensity shortly before the onset of cardiac diastole (which is represented in the electric curve at or near the end of T). From this point it tails away into diastole, disappearing almost entirely before the end of diastole (Figs. 19, 20, and 21) or continuing with lesser amplitude right up to the next first sound (Fig. 20). The variations in duration and intensity from cycle to cycle are well illustrated by Figs. 20 and 21, which were taken from a single patient and are to all intents and purposes continuous curves. The vibrations of these murmurs are very irregular in position and amplitude, giving them their rasping quality. The frequency is from 100 to 130.

Forms of reduplicated sounds. In those patients from whom electrocardiograms are taken which indicate a functional defect of a single auriculo-ventricular bundle branch, and in whom it is supposed that the impulse travels to one ventricle only, though both eventually contract,⁵ reduplication of the first sound is frequent (2). The type of reduplication is a curious one. It may be, as in Fig. 22, that the two elements are alike, each consisting of a number of slow vibrations which resemble those of normal first sounds; but the elements may be dissimilar, in which case the first element is generally of smaller amplitude than the second (Fig. 23), and of a different character. In all instances in which I have recorded the sounds (four cases) the first element has commenced before the ventricular complex, though the greater part of it coincides with the ventricular complex. The second element stands in much the same position as the normal first sound, as a rule a little later, coming either 0.05 to 0.07 second after the opening of the electric deflexions of the ventricle. The first element is properly speaking presystolic, and occurs, in part at least, coincidentally with the auricular contraction; that it is independent of the ventricular systole seems clear from its time relations. The double sound is not due, as might have been thought, to asynchronous action of the two ventricles, resulting from the abnormal path

⁵ The contraction starting in the one ventricle and spreading to the other.

taken by the contraction wave, and consequent asynchronous closure of the valves. To what is it to be attributed? No very certain answer can be given to this question. If we study the reduplication shown in Fig. 22, the resemblance between the two elements is so striking that it is difficult to believe that they had a different origin. It seems probable that both resulted from closure of the auriculo-ventricular valves. It is possible that the valves close twice, once near the end of auricular systole and once at the beginning of ventricular systole, but why such conditions prevail especially in these cases of bundle branch lesion is still not apparent. These heart-sounds are often referred to by the name of 'gallop rhythm'. I have recently obtained a record from a child in which 'gallop rhythm' was audible, but this patient had normal electro-cardiograms. The time-relations of the elements were similar to those already described;⁶ the presystolic element apparently is not peculiar to reduplications where bundle lesions are present. In the cases in which I have observed the abnormality of sounds, the defect has been always in the *right* bundle branch; but this has no necessary significance, for bundle defects are much more common on this side of the heart. Measurements from the four sets of curves are given in the accompanying table in seconds.

Length of Elements.	Beginning of First Element to beginning of Ventricular Complex.	Beginning of Ventricular Complex to beginning of Second Element.	Length of P to beginning of Ventricular Complex.
Case 1. 0.20 (together)	0.03	0.07 approx.	0.15
Case 2. 0.09 0.12 (gap = 0.04)	0.07	0.06	0.16 approx.
Case 3. 0.25 (together)	0.03	0.07	0.15
Case 4. 0.17 (together)	0.04	0.05	0.16

We have seen that reduplication of the second sound may be simulated when premature beats are present. In such instances the first sound of the premature cycle follows closely upon the second of the normal cycle, and if the second premature sound is absent (Fig. 11), or is weak (as in the clinical instance, Fig. 24), the second sound of the normal cycle may appear to be reduplicated. But confusion from this source can scarcely arise except when the premature cycle falls immediately after the normal one (as in Fig. 11). An example of the reduplicated second sound of mitral stenosis was given in my earlier paper (8), and in this the elements of the double sound were close together and equal in character and amplitude.

Such reduplication has to be distinguished from the reduplication caused by the presence of what is known as the third heart-sound (6), an example of which is shown in the last figure (Fig. 25). The third sound lies in mid-diastole, and, in this instance, some 0.18 second from the commencement of the second sound and during the contraction of the auricle. Generally speaking it associates

⁶ In three other instances the additional sound of the 'gallop' lay in diastole, midway between second and first sounds; one of these cases was a patient who exhibited auricular fibrillation.

itself with a slow heart action and has been attributed to a secondary closure of the auriculo-ventricular valves; it possibly has this origin in some cases, but the explanation will not hold good in the present one, for as the auricles were in contraction the valves leading to the ventricles must have been patent. The auricle is known to give rise to a sound by its contraction in some cases, especially in complete heart-block,⁷ and it may be that the sound of Fig. 25 is in reality of auricular origin; the time-relations certainly suggest it. But when we are dealing with so complex a movement as that of the heart-beat, the origin of abnormal sounds is often difficult to explain, and I hesitate to offer final explanations for the phenomena discussed until more material has been collected. The curves serve to illustrate the complexity of the problem of reduplication generally and to emphasize the need of studying it graphically.

⁷ I have since been able to record these sounds in complete heart-block; they fall with fixed relations to those auricular systoles which occur in diastole.

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DESCRIPTION OF FIGURES.

PLATE 19, FIG. 3. Simultaneous electro-cardiograms, carotid curve (Hürthle), and heart-sound record, from a dog during a period of apnoea. The electro-cardiograms in this and all other figures are from lead II. The heart-sounds in this figure and in Fig. 4 were taken from the left fifth space, $1\frac{1}{2}$ inches from the middle line. The time-marker is in 1/30th seconds. The hard vertical line indicates the commencement, the vertical dotted line indicates the end of ventricular systole.

FIG. 4. Simultaneous electro-cardiogram, carotid curve (Hürthle), and heart-sound record, taken from a dog during a period of apnoea.

FIG. 5. Heart-sound record taken from the apex of a normal human subject. The first sound commences with small initial deflexions which increase in amplitude until the centre of the sound is reached, from which point they decrease. The second sound is of larger amplitude at its onset and decreases in intensity. The rate of the vibrations is very similar for first and second sounds.

PLATE 20, FIG. 6. Simultaneous electro-cardiogram, carotid curve (Hürthle), and heart-sound record, taken from a dog and showing the effects of a rise of arterial pressure resulting from obliteration of the abdominal aorta. A rise of the systolic pressure of 30 millimetres of mercury is shown. The first and second sounds retain their original amplitudes.

FIG. 7. The end of a period of tachycardia and the resumption of the normal rhythm in a dog. The tachycardia was produced by stimulating the auricle with rhythmic induction shocks by means of electrodes introduced through the jugular vein. During the period of tachycardia, the first and second sounds are reduced in amplitude and are also reduced slightly in duration.

FIG. 8. Simultaneous electro-cardiogram and heart-sound record from a dog, subsequent to the rupture of a single aortic cusp. The second sound is accompanied and succeeded by a murmur (M), which shows distinctly in the record for a period of a little more than 1/30th second. It consists of a number of quick vibrations which decrease rapidly in amplitude.

PLATE 21, FIG. 9. Simultaneous electro-cardiogram and heart-sound record, taken from the fifth left space, two inches from the middle line, from another dog, in which a dorsal aortic cusp had been destroyed. With the second heart-sound and following it is a number of rapid vibrations, giving rise to an early diastolic murmur (M), and similar to those of Fig. 8, though of longer duration. Preceding the first sound is a second murmur (PM), which has a much lower frequency and occupies the position of presystole. It varies in degree and duration from cycle to cycle. Presumably it was of the same nature as the murmur described by Flint.

FIG. 10. A heart-sound record from a dog, showing a single premature contraction of auricular origin. Accompanying the premature beat, the first and second sounds are reduced in amplitude; the interval between them is reduced; they are altered in character and slightly reduced in duration. The first sound of the post-extrasystolic contraction is increased in amplitude and duration.

FIG. 11. A bigeminal action of the heart produced in the dog by interrupted stimulation of the auricle through the jugular vein. The rate of stimulation is so arranged that a premature beat follows each normal cycle. The normal cycles are accompanied by first and second sounds. The premature cycle is accompanied by a first sound; the second is absent. The first sound accompanying the premature beat is altered in character; it is of very short duration and has a small amplitude. While the heart-beats are bigeminal, the sounds are tripled. The record resembles a reduplication of the second sound.

PLATE 22, FIG. 12. Records from the same animal, showing a bigeminal action in which the beats are more separated. Under this circumstance the premature beat gives rise to a first and second sound. The heart-sounds are consequently arranged in groups of four.

FIG. 13. Electro-cardiogram and heart-sound record from an animal in which the auricles were fibrillated by faradization through the jugular vein. The action of the heart is irregular and the amplitudes and duration of the first and second sound, and also the interval between first and second sounds, vary with the lengths of pause preceding the beats which give rise to them. From time to time, when a beat is very premature, the second sound is absent and the first sound stands alone.

FIG. 14. Simultaneous electro-cardiogram and apical heart-sound record from a patient with mitral regurgitation. The first and second sounds are shown. Following upon the first sound is a series of minute and rapid vibrations produced by the murmur (s.m.). They are just visible with the aid of a magnifying glass. The murmur was very audible.

PLATE 23, FIG. 15. Apical heart-sounds from a patient who presented a loud systolic mitral murmur. The murmur is shown at s.m. and consists of a number of rapid and almost uniform oscillations confined to mid-systole.

FIG. 16. A similar murmur (s.m.) in another patient. This murmur had a faint musical quality.

FIG. 17. A record from the aortic cartilage in a case of aortic disease, showing rough to-and-fro murmurs. There is a trace of the first sound, but it is interrupted almost immediately by a systolic murmur of diminuendo type. This is succeeded by a long diastolic murmur which at first increases in intensity and subsequently decreases.

FIG. 18. A record from a case of aortic disease, showing a musical murmur which occupies the whole of diastole. Musical murmurs are characterized by the uniformity in the position and amplitude of the vibrations of which they consist.

PLATE 24, FIG. 19. A record from a case of congenital abnormality of the heart; taken over the pulmonary cartilage. The murmur was a continuous one and seemed to be accentuated in systole and early diastole. The murmur commences near the end of the first sound; its amplitude increases until the end of systole and then decreases rapidly, to be continued throughout diastole. The first sound in this and other figures may be recognized from its position and from the relatively low vibration frequency.

FIGS. 20 and 21. Two records from a similar case. The murmur is of the same kind as that shown in the last figure. It commences immediately after the completion of the first sound, increases in intensity until the systole is almost complete, and tails away with diastole. In Fig. 20 it is continued through diastole up to the next first sound, and the amplitude is irregular. In Fig. 21 it is practically lost in mid-diastole.

PLATE 25, FIG. 22. Electro-cardiogram and heart-sound record from a patient exhibiting reduplication of the first sound. The reduplication was audible over the whole of the lower precordium, but was most conspicuous in the fourth left space two inches from the mid-line, at which point the record was taken. The first element of the reduplication lies in presystole. The electro-cardiogram is of abnormal type and indicates a lesion of the right bundle branch. (The curves from the other leads were characteristic. In lead I a conspicuous summit of long duration was followed by a broad downward deflexion; in lead III a conspicuous depression of long duration was followed by a broad upward deflexion).

FIG. 23. Similar curves in another case of the same kind. The sound record is more unsteady, but the separate elements are clearly distinguishable. The first element of the reduplication commences in presystole. (The other electro-cardiographic leads showed similar curves to those described under Fig. 22, being characteristic of a right bundle branch lesion.) The sound curve was taken from the apex beat. It shows also a finely cut early diastolic murmur; the case was one of aortic disease.

FIG. 24. Apical heart-sounds and electro-cardiogram in the human subject, showing a single premature beat of auricular origin. The premature beat is accompanied by first and second sounds; the second sound is of small amplitude. The first sound of the post-extra-systolic contraction is intensified.

FIG. 25. Electro-cardiogram and heart-sound record, taken from the apex beat of a young subject and showing first, second, and third heart-sounds. In this instance the third sound occurs during the systole of the auricle.

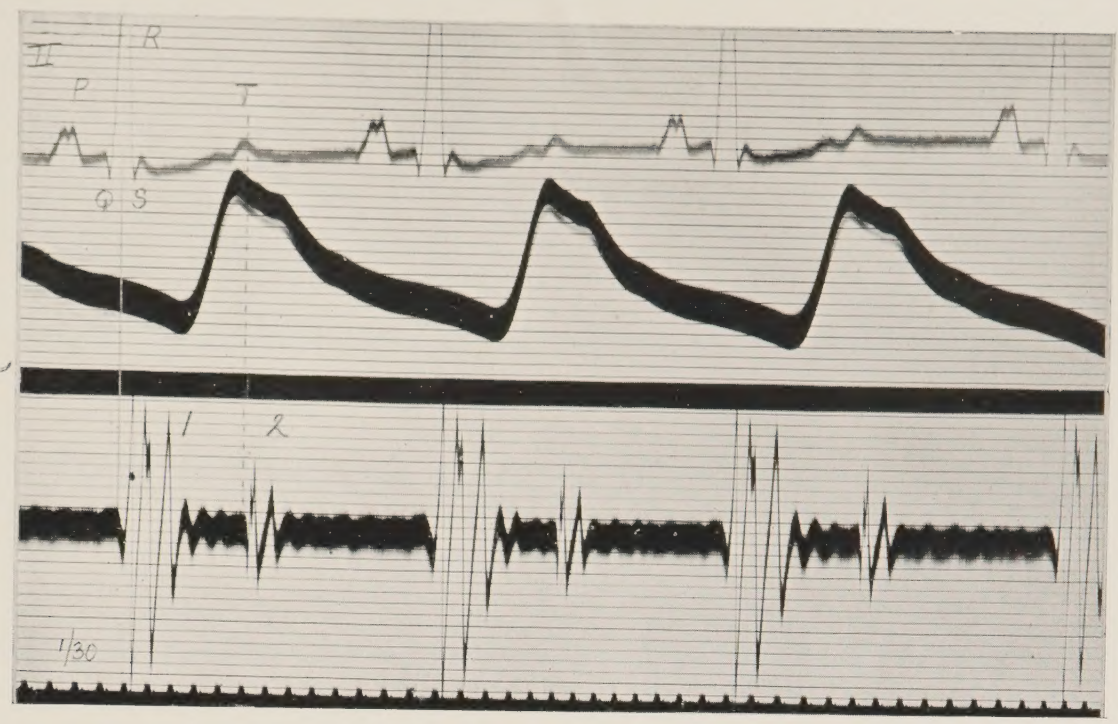


FIG. 3

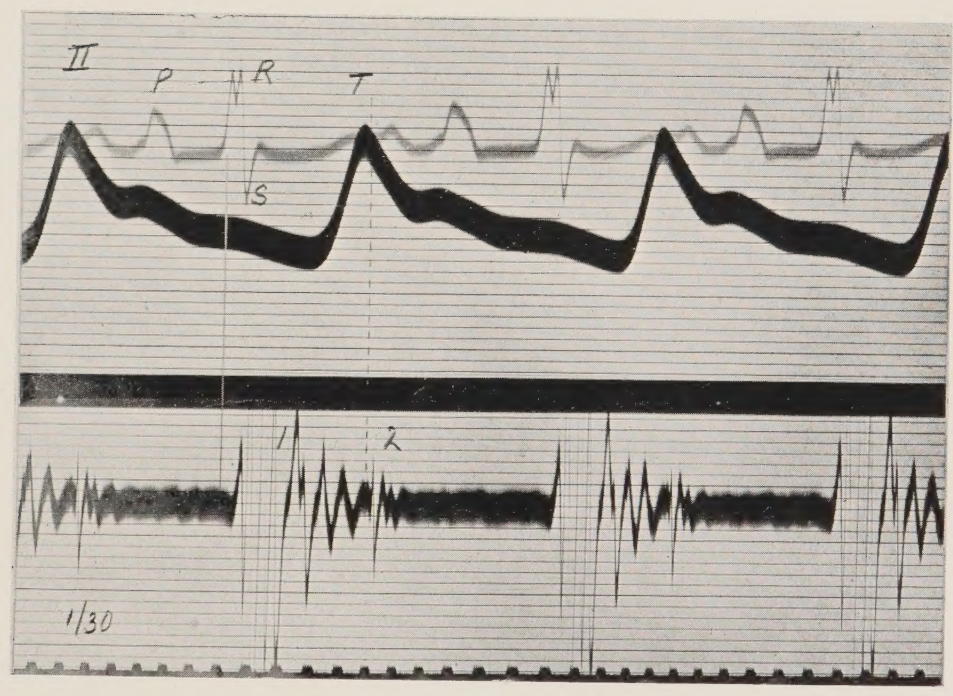


FIG. 4

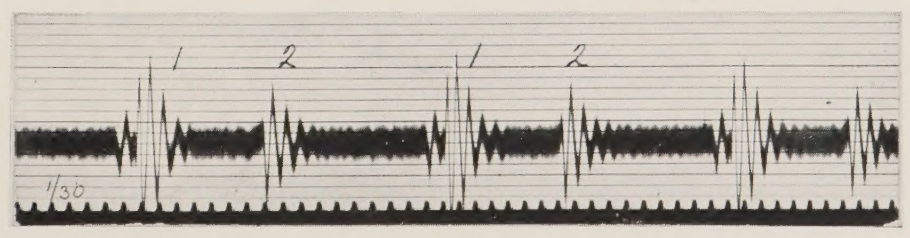


FIG. 5

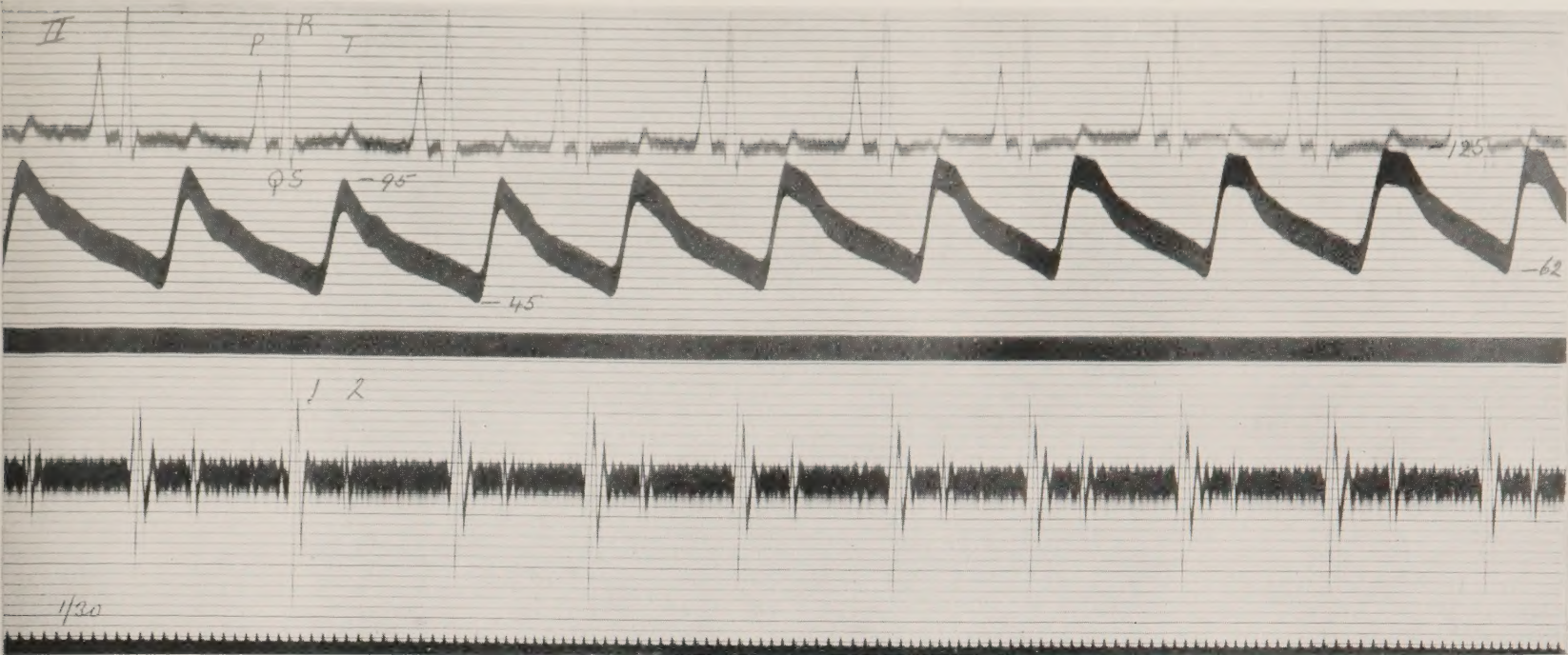


FIG. 6

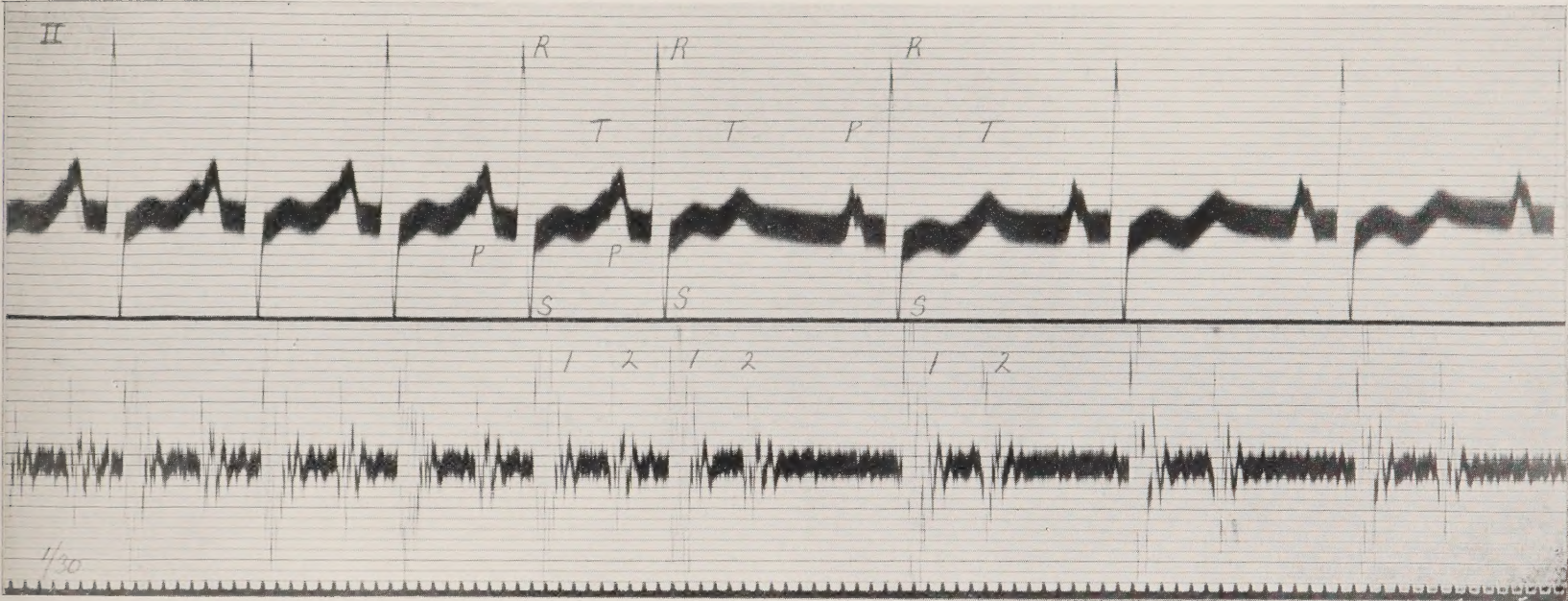


FIG. 7

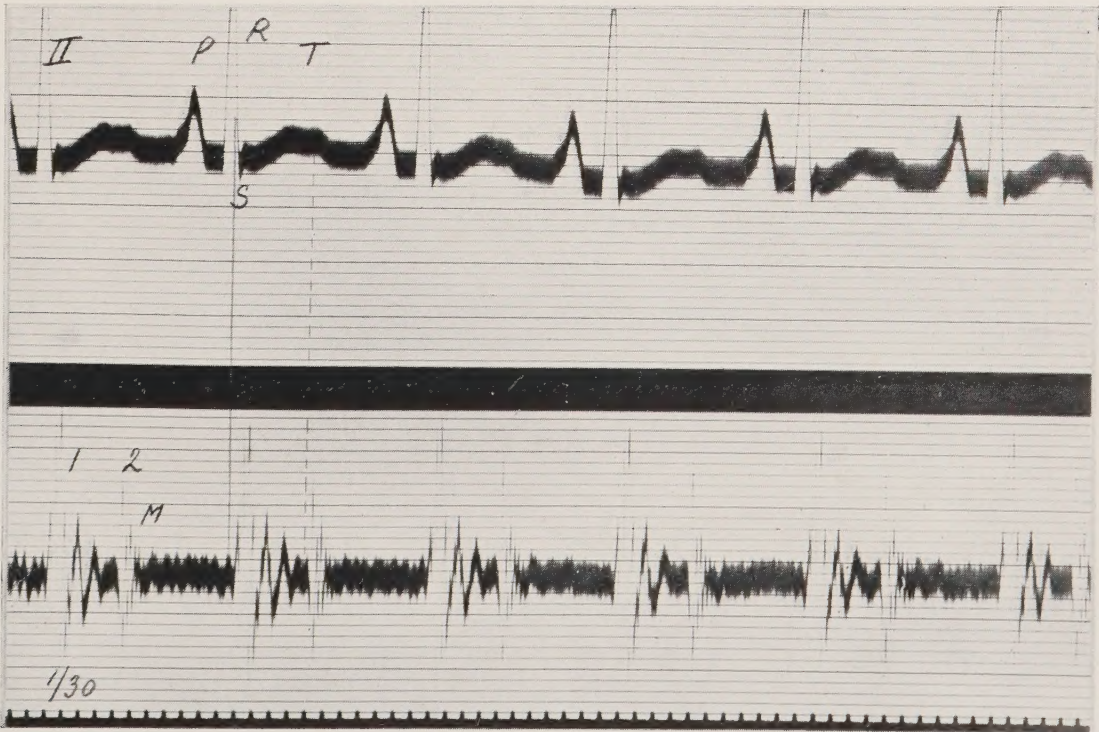


FIG. 8

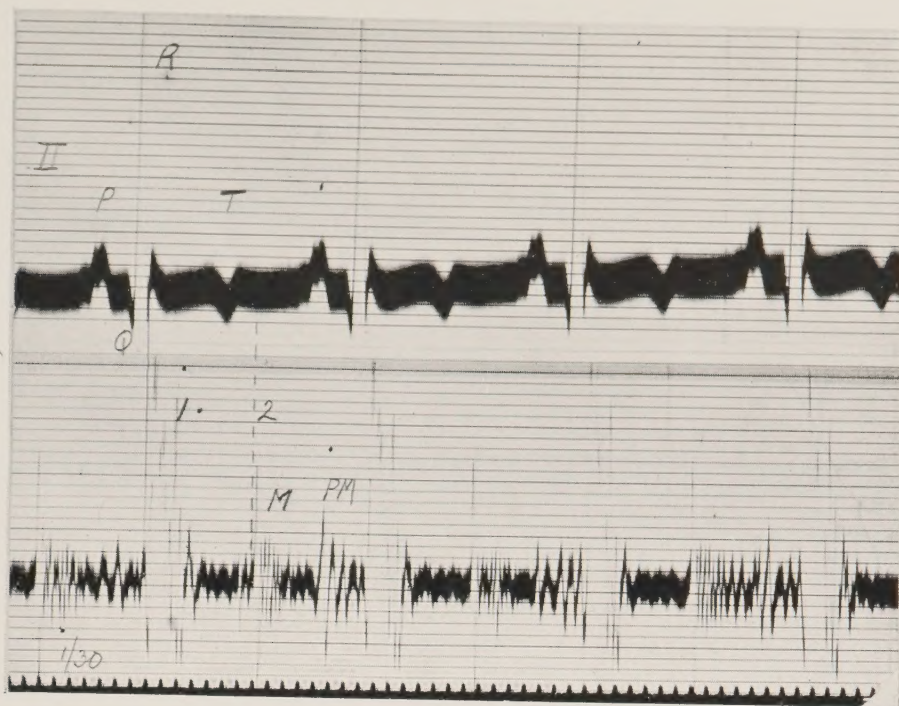


FIG. 9

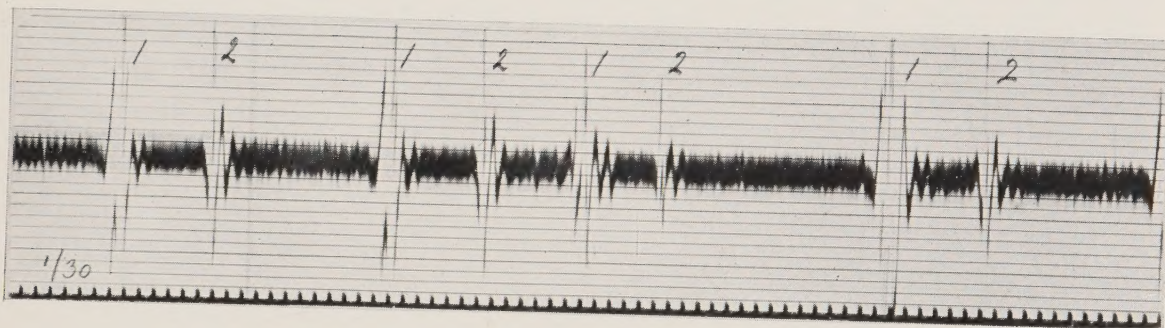


FIG. 10

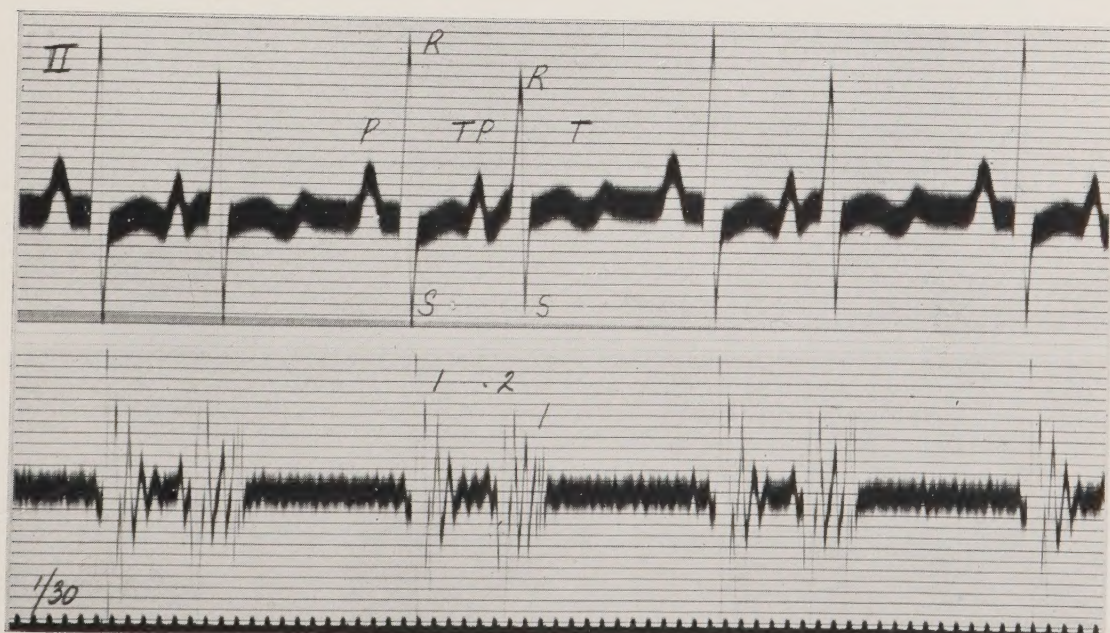


FIG. 11

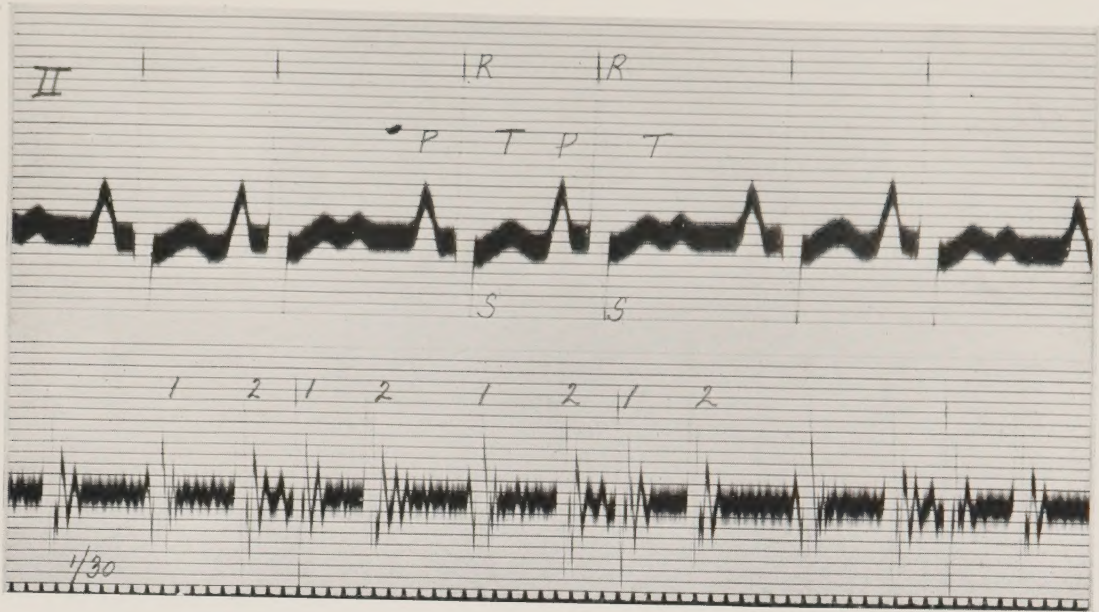


FIG. 12

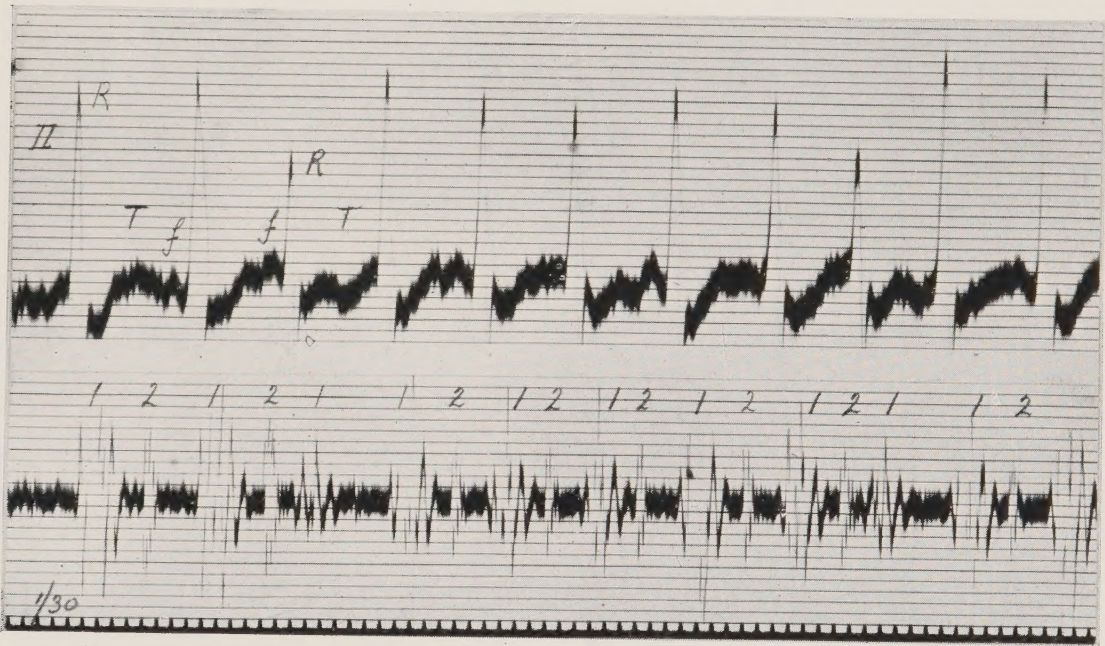


FIG. 13

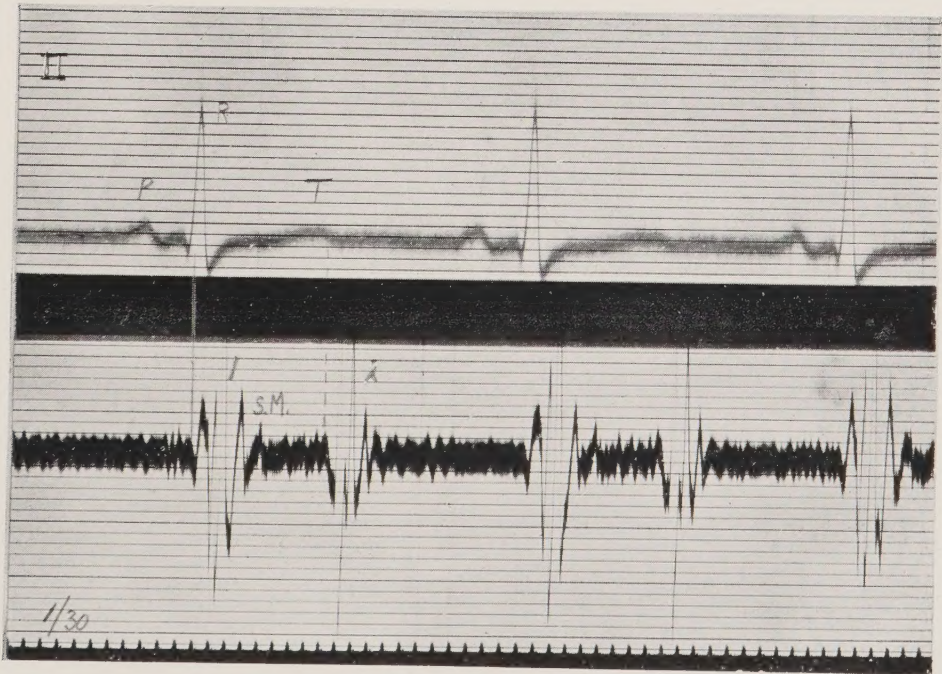


FIG. 14

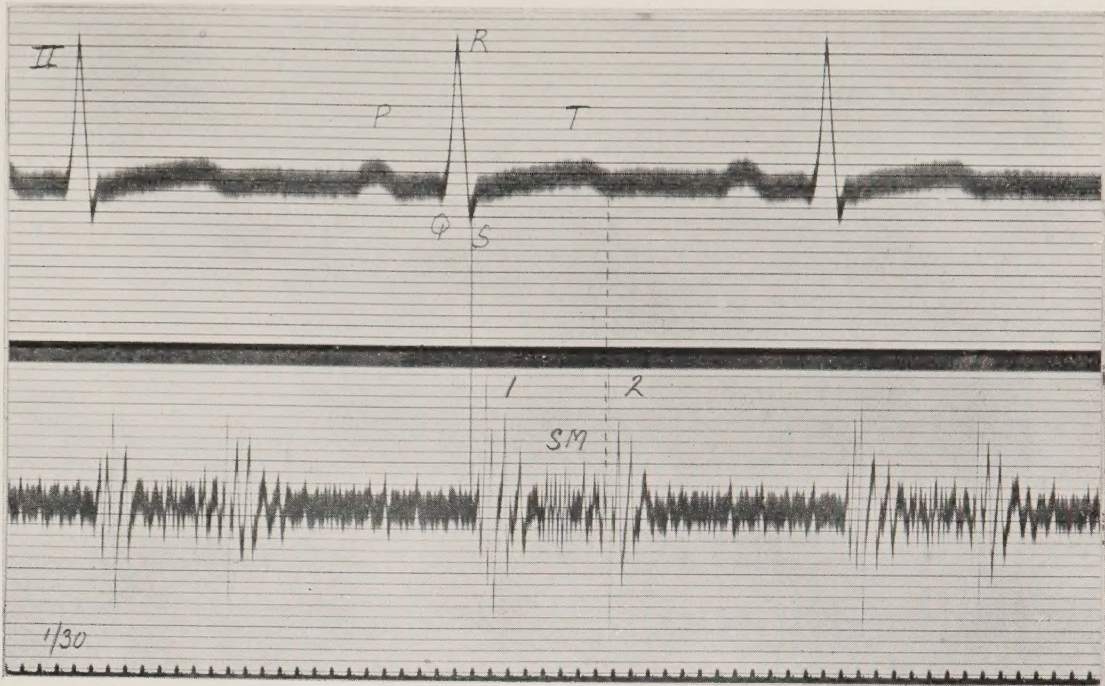


FIG. 15

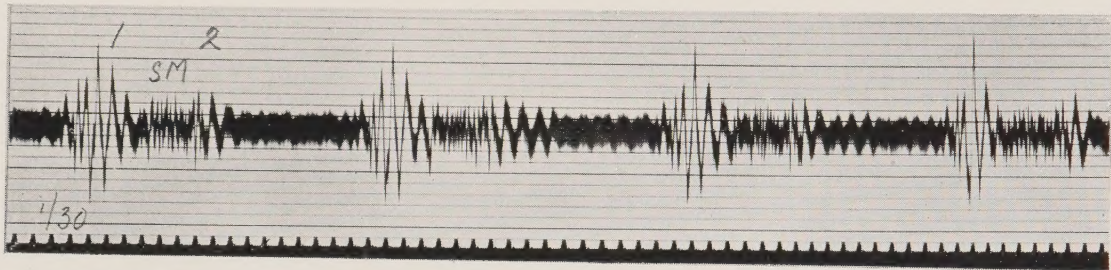


FIG. 16

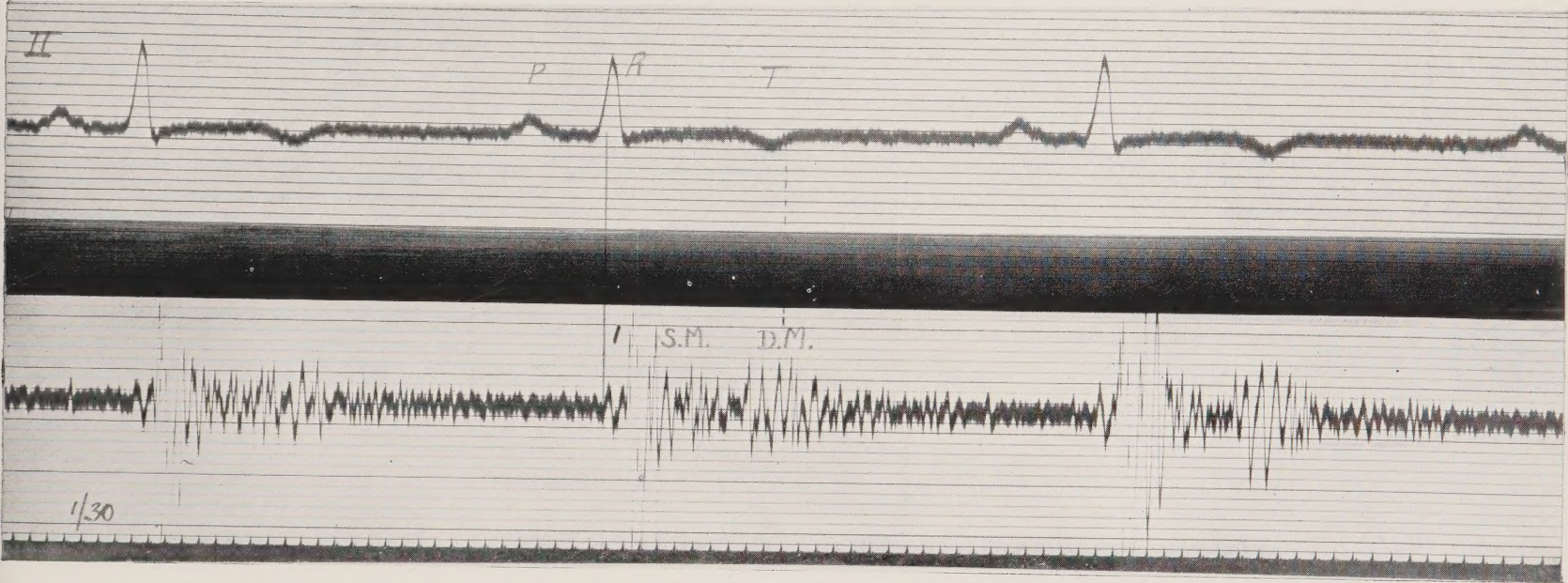


FIG. 17

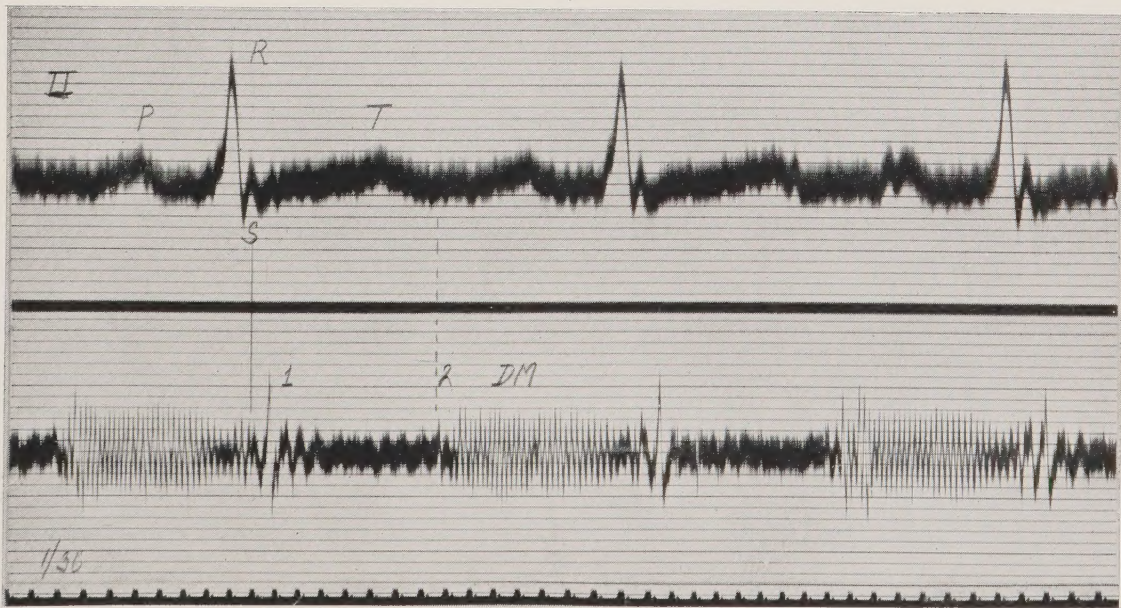


FIG. 18

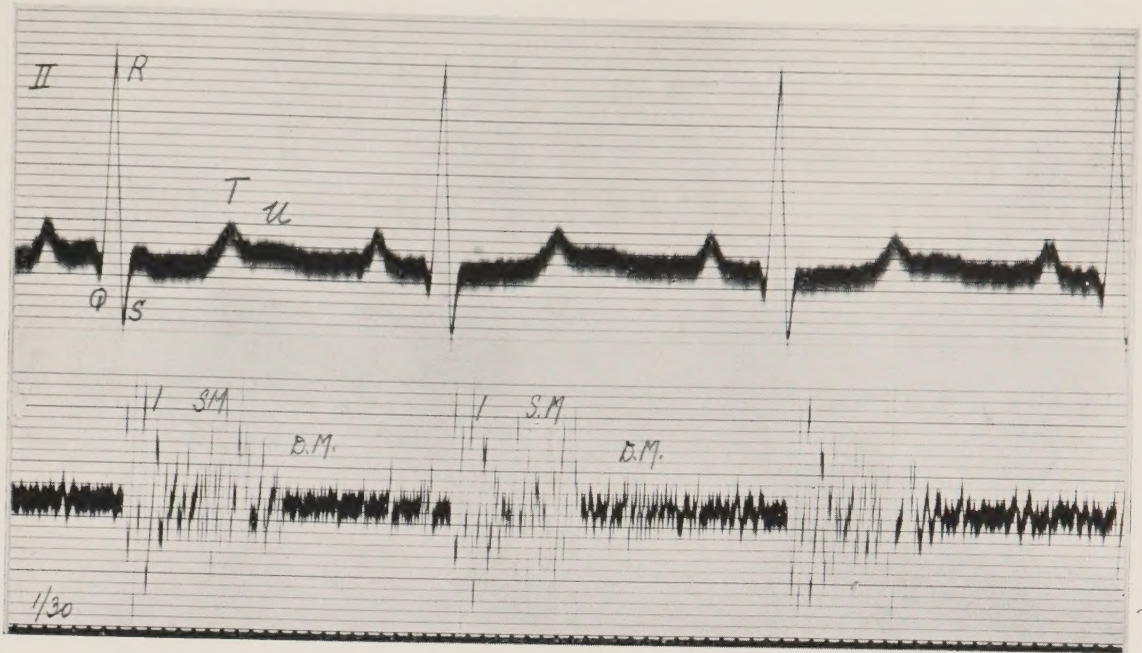


FIG. 19

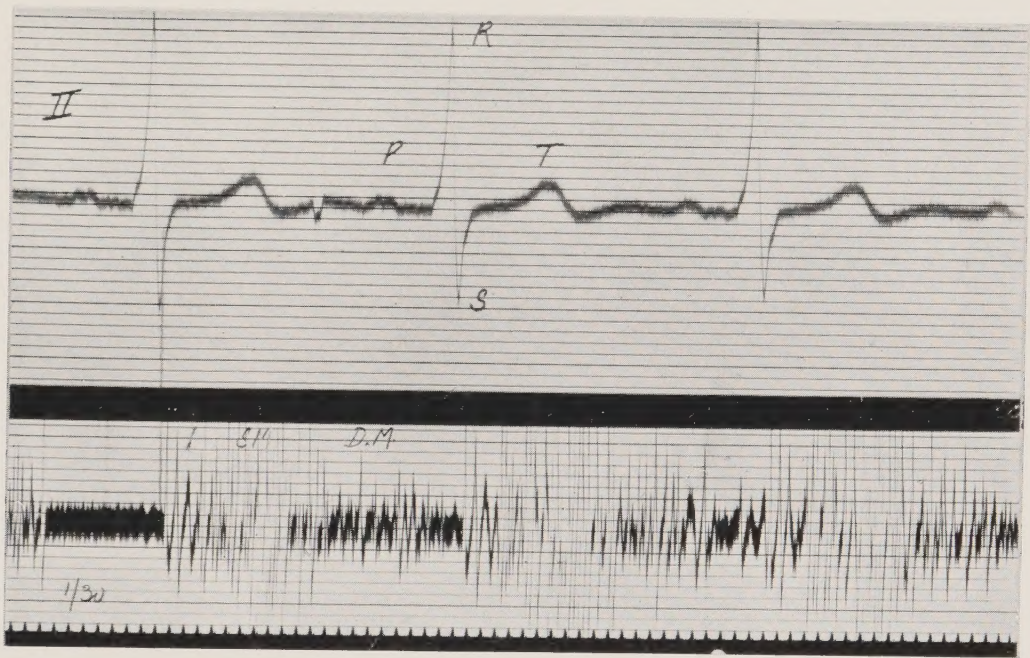


FIG. 20

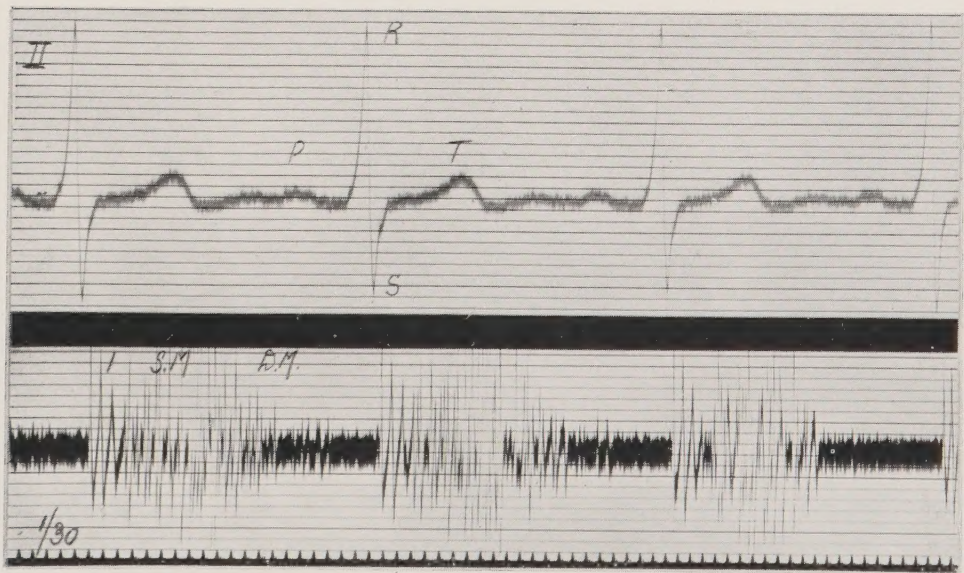


FIG. 21

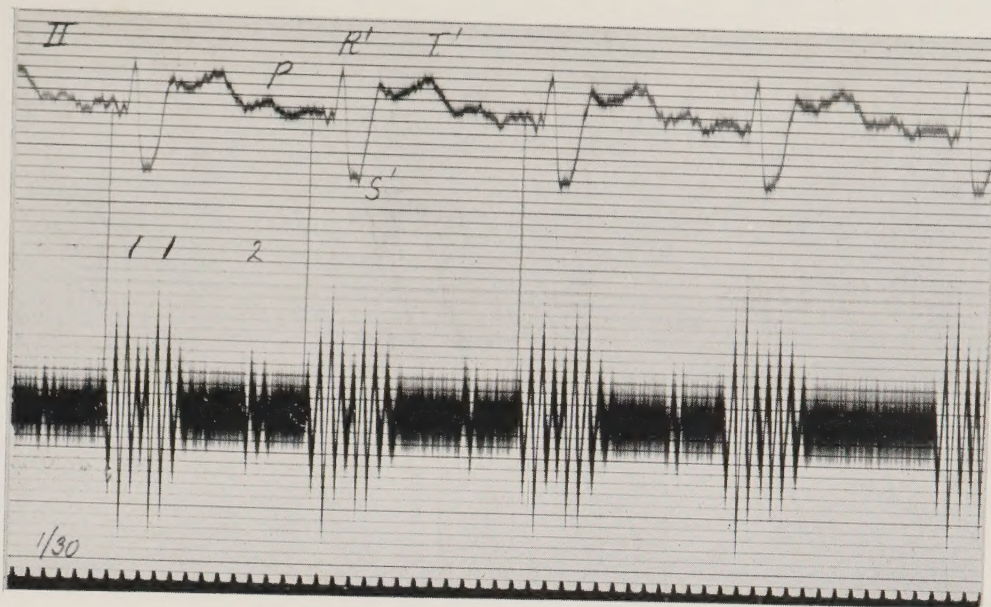


FIG. 22

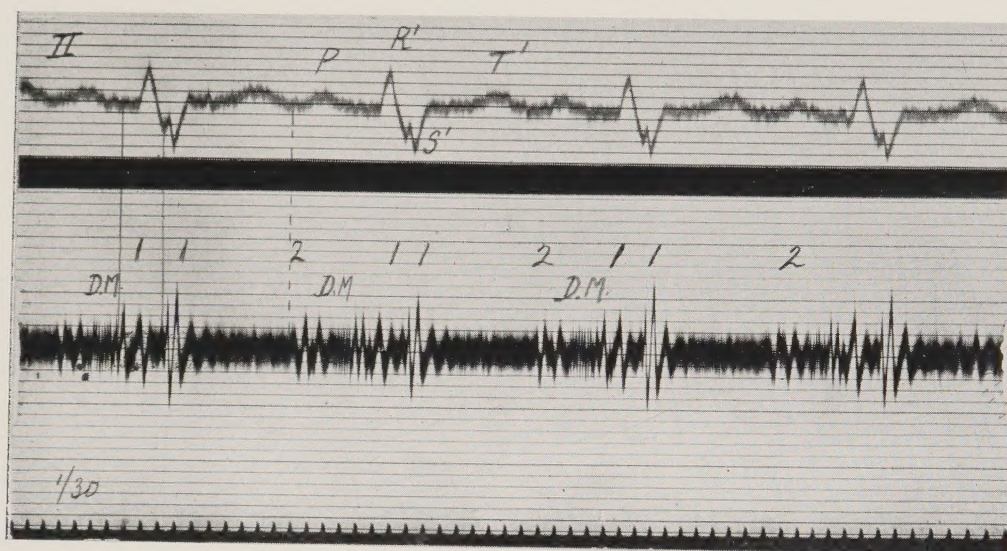


FIG. 23

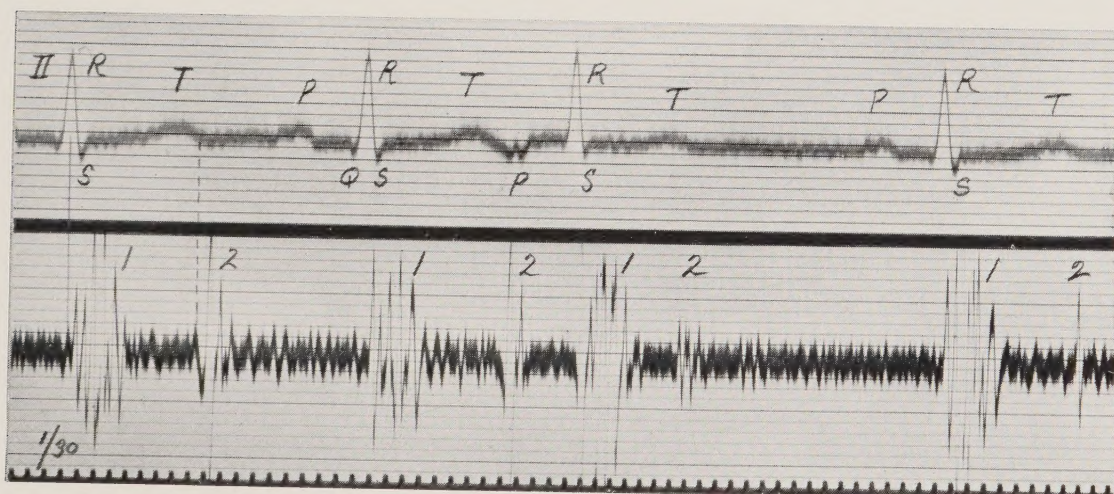


FIG. 24

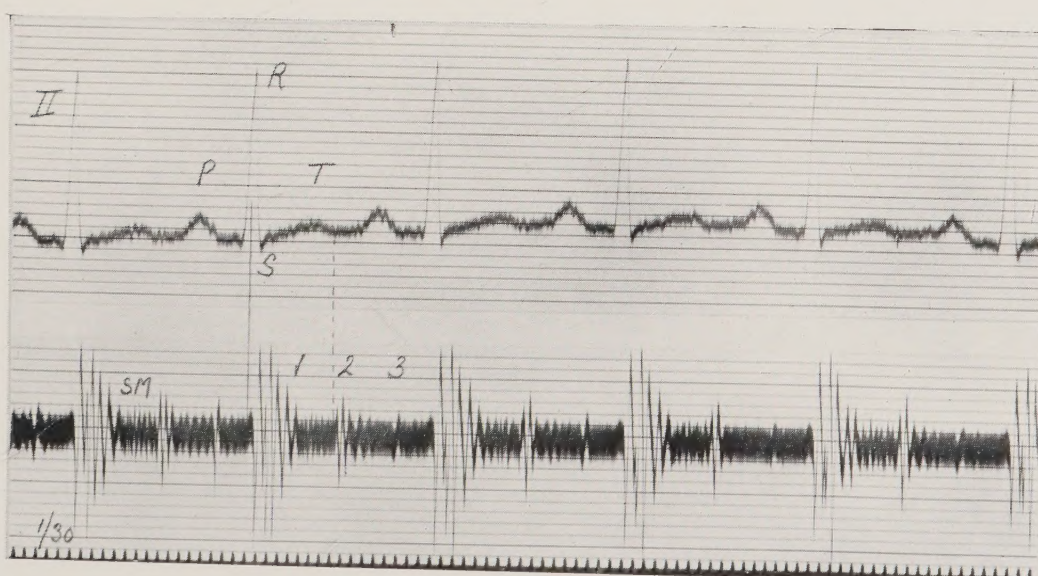


FIG. 25

